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G1A

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(54) Detection of coating adhesion

(57) To detect defective adhesion of a coating 12 to a substrate 6, eg a turbine blade, heat is transferred to the material and temperature differentials are measured at selected positions on the material. A fault in the lamination at 9 will be indicated by a difference in the temperature at the position of the fault as compared with temperatures occurring at other positions eg 30. Heating may be by hot air or a laser beam scanned across the material, and the resulting temperature/time response is detected by an I.R. camera.

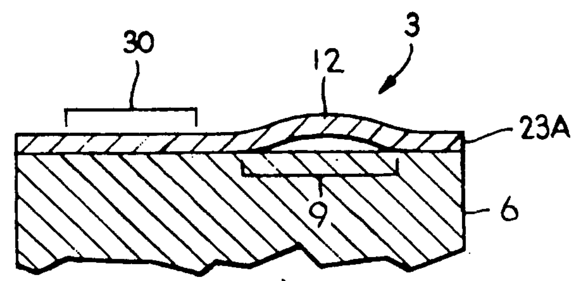

Fig 1

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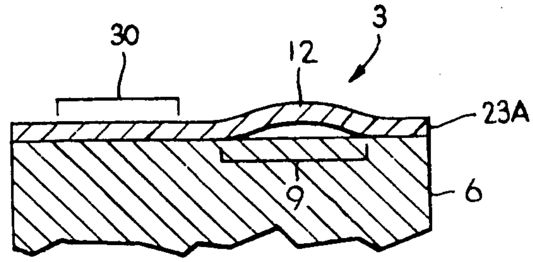


Fig 1

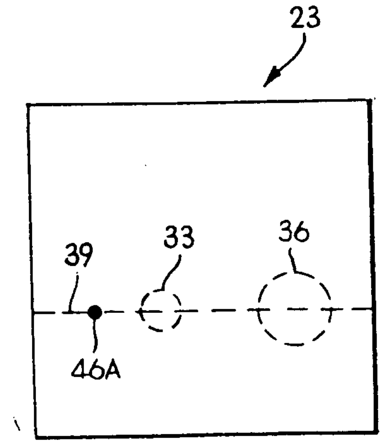


Fig 3

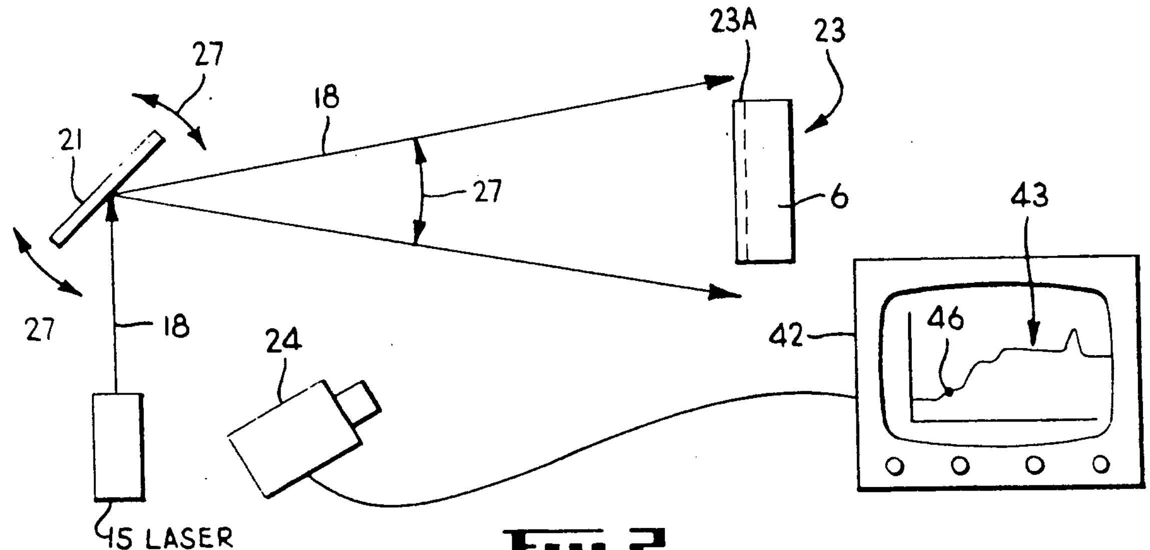


Fig 2

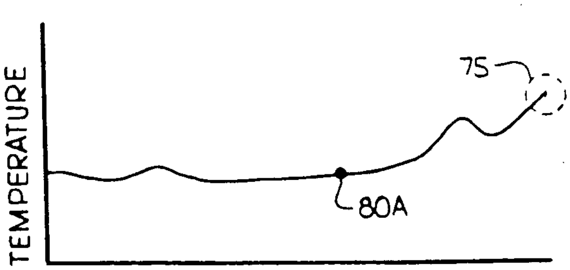


Fig 4A

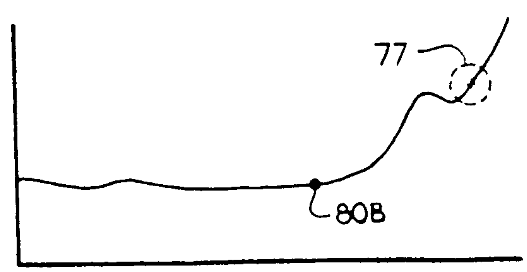
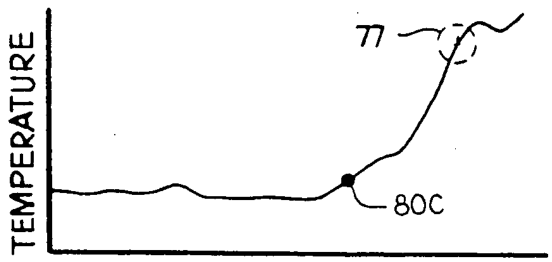
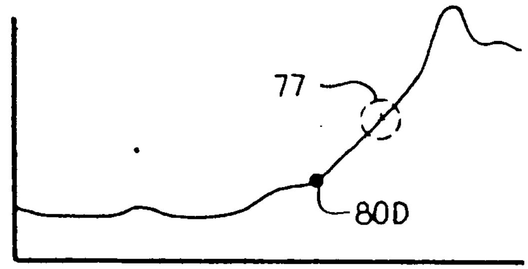


Fig 4B



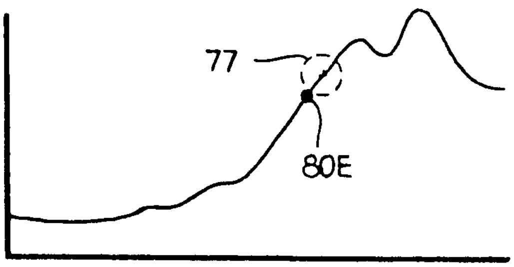
TIME = 1.10

Fig 4C



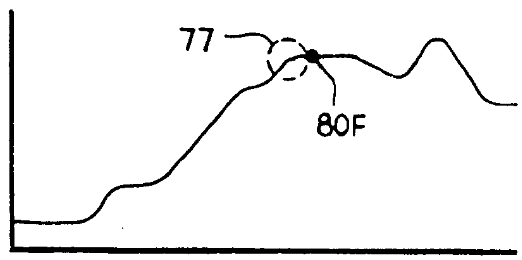
1.20

4D



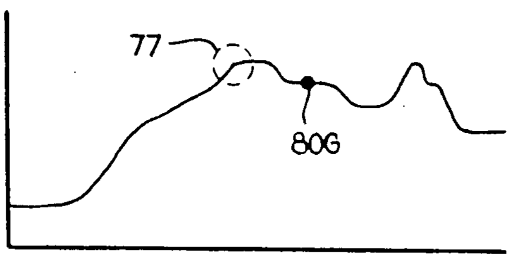
1.30

Fig 4E



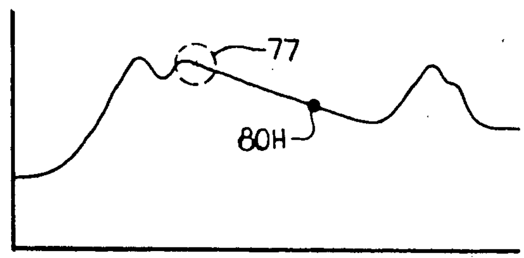
1.40

Fig 4F



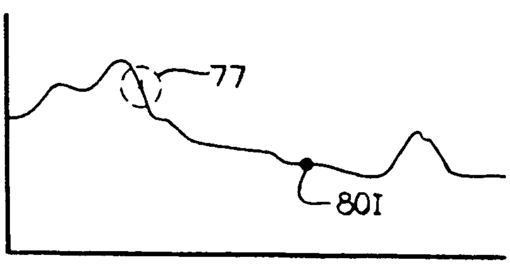
1.50

Fig 4G



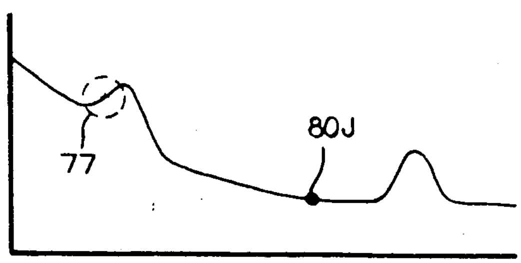
1.60

Fig 4H



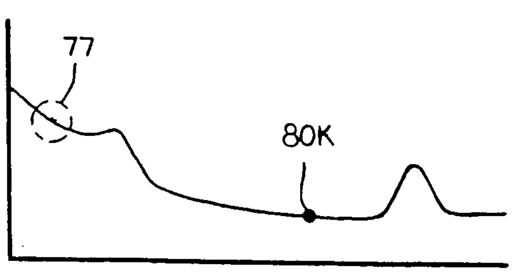
1.70

Fig 4I



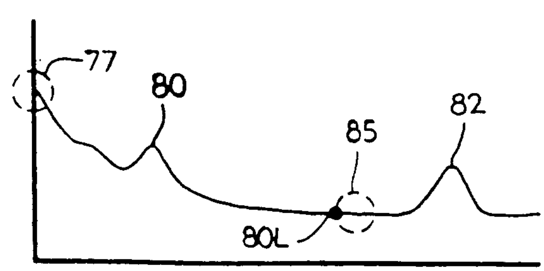
1.80

Fig 4J



1.90

Fig 4K



2.00

Fig 4L

SPECIFICATION

Detection of coating adhesion

The present invention relates to the detection of defective adhesion (i.e., detection of bubbles or "disbonds") of a coating applied to a surface.

BACKGROUND OF THE INVENTION

The turbine blades in a gas turbine engine are impinged upon by hot gases and, as is well known, the hotter the gases, the more efficient is the thermodynamic cycle of the engine. However, high temperatures tend to degrade the turbine blades. Thus, a protective thermal barrier coating (TBC) is commonly applied to the blades.

One type of TBC is a layer between 3 and 16 mils thick (a mil being 1/1000th of an inch) of zirconium oxide stabilized with 8% yttria (Y_2O_3). In order for the TBC to be effective, it must be securely bonded to the blade without bubbles or disbonds as shown in Fig. 1. In that Figure, a disbond 3 does not adhere to the metallic substrate 6 of the blade at region 9. Disbonds are undesirable because unbonded material 12 can spall from the blade, thus leaving the metal in region 9 unprotected.

Accordingly, in TBC application, it is desirable to detect regions of faulty adhesion, i.e., disbonds, of the TBC coating.

OBJECTS OF THE INVENTION

It is an object of the present invention to provide a new and improved system for measuring the adhesion of a coating to a surface.

It is a further object of the present invention to provide a new and improved system for detecting disbonds in a thermal barrier coating of a gas turbine engine blade.

SUMMARY OF THE INVENTION

In one form of the present invention, heat is transferred to a laminated material and temperature differentials are measured at selected positions on the material. A fault in the lamination will be indicated by a difference in the tenperature at the position of the fault as compared with temperatures occuring at other positions.

BRIEF DESCRIPTION OF THE DRAWING

Figure 1 illustrates a disbond 12 in a laminated material.

Figure 2 illustrates one form of the present invention.

Figure 3 illustrates the path 39 which a laser beam 18 in Fig. 2 follows in scanning a target 23.

Figure 4A–L illustrate temperature-position plots of the target 23 in Fig. 2 taken at 0.10 second intervals.

DETAILED DESCRIPTION OF THE INVENTION

Fig. 2 illustrates one form of the present invention, wherein a laser 15, which is preferably a YAG laser such as Model No. 512Q, available from Control Laser Corporation, located in Orlando, Florida, generates a laser beam 18 which is projected to a scanning mirror 21 which reflects the laser beam 18 to a target 23. The target 23 is shown as a block, but it can be a gas turbine engine blade. The target 23 contains a metallic substrate 6 bearing TBC 23A. A scanning infrared radiometer 24 (termed IR camera) such as Model No. 525, available from Inframetrics, located in Bedford, MA., is directed toward the target 23 to receive the image of the target 23. The scanning mirror 21 scans the laser beam 18 across the target 23 as shown by arrows 27.

When the laser beam 18 strikes region 30 in Fig. 1 (laser beam 18 is not shown in Fig. 1), a region in which the TBC is properly bonded, the TBC heats up. However, because of the good bond to the metal substrate 6, rapid heat transfer occurs and the heat imparted by the laser beam 18 to the TBC is dissipated by the metal substrate 6. In contrast, when the laser beam 18 strikes the disbonded region 9, the absence of a bond in region 9 inhibits good heat transfer into the substrate 6. That is, the TBC, in being a ceramic material having a low heat transfer coefficient, tends to retain heat imparted to it by the laser beam. However, if the TBC is in contact with the metallic substrate 6, which has a much higher heat transfer coefficient (perhaps 2–3 orders of magnitude greater), then the metallic substrate carries away the heat. The differential heating of the properly bonded region 30 as compared with the disbonded region 9 can be detected by the IR camera. An example of such detection will now be discussed.

The target 23 in Fig. 2 was constructed of a 2-inch square substrate of Hastelloy X (Hastelloy is a trademark of Cabot Corporation, Kokomo, Indiana). The substrate was 0.125 inches thick and was vacuum plasma sprayed with a 5 to 8 mil thick bonding layer of NiCrAlY alloy, followed by a plasma spray coating of zirconium oxide (ZrO_2) stabilized with 8% yttria (Y_2O_3). Disbonds 33 and 36 in Fig. 3 were artificially generated by applying a braze inhibitor known in the brazing art as "stop off." Disbond 33 was 0.250 inches in diameter and disbond 36 was 0.375 inches in diameter.

The scanning mirror 21 in Fig. 2 scanned the reflected laser beam 18 along a scan line 39 in Fig. 3. The laser spot size (the diameter of the beam striking the TBC coating) was 0.157 inches and the laser was operated at a power of approximately 50 watts. The laser spot was scanned across the surface of the TBC at a speed of approximately 1 inch per

second.

The IR camera 24 in Fig. 2 received an image of the scan line 39 in Fig. 3 and produced a plot 43 on its outpur monitor 42 in Fig. 2 of the TBC temperature vs. position on the scan line. For example, the temperature at point 46 in Fig. 2 corresponds to point 46A in Fig. 3. The plot varied with time as shown by Figs. 4A–K. These Figs. represent the actual plot configurations existing at the times indicated by the labels beneath them.

At t=0.90 sec., the plot resembled that of Fig. 4A. The reader will note a rise in temperature, in region 75, at the the right side of the plot. This rise results from the fact that the scanning laser beam is about to enter the field of view of the camera, from the right. This is more clearly shown in Fig. 4B, where the laser beam has entered the view of the camera and is located approximately in region 77. A rise in temperature occurs in this region 77. Figs. 4C–4L illustrate the temperature changes occuring as the laser beam scans across the field of view of the camera, right to left, the laser spot occupying the approximate region indicated as dashed circle 77. As the laser spot leaves the field of view, two residual hot peaks 80 and Fig. 4L remain. These peaks correspond to the disbonds 33 and 36 in Fig. 3 and these peaks occur for the reasons discussed above.

Applicants wish to emphasize the following three points. One, the preceding discussion has considered heating of the TBC, followed by ascertainment of regions of differential cooling (i.e., peak 82 in Fig. 4L looks differently than region 85). However, heating of the TBC is not necessary, but cooling can be used, as by application of a cold gas, followed by ascertainment of regions of differential heating. Thus, the invention entails the transfer of heat to a coating substrate system, followed by detection of regions having different temperatures. In the case of heating the coating, heat transfer would be positive (in the algebraic sense); in cooling, negative.

A temperature transient is the temperature-vs.-time history of a region of the coating. For example, points 87A–L in Figs. 4A–L represent a temperature transient of the region of the coating 23A with which they are associated.

Two, the preceding discussion has described heating of the target 26 using a laser operating at a given power, with a given spot size, and a given scan speed. Given that one watt=one Joule/sec., a 30-watt laser scanning a spot size of .02 sq. in. at one inch per second delivers 1500 Joules per sq. in. per second. Thus, the heating can be described in terms of projecting 1500 Joules per sq. in. per second toward the TBC. It is noted that the power (i.e., the Joules per second) is measured at the laser, while the spot size and the scanning speed are measured at the TBC. Consequently, the description above does not consider the efficiency of energy transfer between the laser and the TBC, although the efficiency is generally quite high.

Thus, the preceding discussion has considered comparison of the temperature of TBC regions which are physically located on the same laser scan. However, such need not be the case. One can ascertain the temperature of properly bonded TBC and use it as a reference instead of a region, such as region 85 in Fig. 4L, as a reference.

An invention has been described wherein the differential heat dissipation between a disbonded thermal barrier coating and properly bonded TBC is used to detect the disbond. A laser is used to heat both regions and a scanning infrared radiometer is used to measure the temperature of both regions as a function of time. It has been found that the temperature of the disbonded region remains higher for a measurable length of time. The present invention utilizes this finding for the detection of the disbonds.

Numerous substitutions and modifications can be undertaken without departing from the true spirit and scope of the present invention. For example, a laser need not be used for heating; hot air or a radiant heat source can be substituted, Further, the preceding discussion has considered the TBC of a gas turbine engine blade. However, the present invention is not limited to detection of disbonds of TBC on blades, but can be used to detect disbonds in other engine components, Still further, the principles of the present invention can be extended to detection of disbonds generally, in any laminated material.

What is desired to be secured by Letters Patent is the invention as defined in the following claims.

CLAIMS

1. A method of detecting the absence of contact between a coating and a substrate, comprising the following steps:

(a) transferring heat to the coating;

(b) measuring the temperature differentials of the coating at selected positions;

(c) comparing selected ones of the measured temperatures with a reference.

2. A method of detecting a disbond between a thermal barrier coating (TBC) and a gas turbine engine component comprising the following steps:

(a) scanning a laser beam across the TBC for heating the TBC;

(b) measuring the temperature of the TBC following heating using a scanning infrared radiometer;

(c) ascertaining the occurrence of differential cooling of the TBC.

3. A method of detecting a disbond between a thermal barrier coating (TBC) and a gas turbine engine component, comprising the

following steps:

(a) applying energy to the TBC in order to change the temperature of the TBC sufficiently to generate measurable thermal gradients at the surface of the material;

(b) terminating the energy delivery to the TBC;

(c) monitoring the temperature of the TBC to detect different rates of heating or cooling at different regions of the TBC.

4. A method according to claim 3 in which the heating of the TBC is accomplished by projection of laser energy onto the TBC at a rate of approximately 2500 Joules per sq. in. per second.

5. A method as claimed in claim 1 and substantially as hereinbefore described.

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